CAPABILITY OF DETECTING RAPID SUBSIDENCE WITH COSMO SKYMED AND SENTINEL-1 DATASET OVER KONYA CITY

Fatma CANASLAN ÇOMUT [(1)], Aydın USTUN [(2)], Milan LAZECKY [(3)], Daniele PERISSIN [(4)]

[(1)] Disaster & Emergency Directorate of Denizli (AFAD Denizli), 20 010, Turkey , Email:fatma.c.comut@afad.gov.tr
[(2)] Kocaeli University Engineering Faculty Geomatics Engineering, 41 135, Turkey, Email:aydin.ustun@kocaeli.edu.tr
[(3)] IT4Innovations,VSB - TU Ostrava, 17 listopadu 15, 708 33 Ostrava, Czech Republic, Email: milan.lazecky.st@vsb.cz
[(4)] Lyles School of Civil Engineering, Purdue University, USA, Email: daniele.perissin@sarproz.com

ABSTRACT

The current state of work demonstrated in this paper is maps of the spatial and temporal patterns of deformation at ground subsidence by using advanced InSAR methods at specific areas surrounding Konya closed basin and its near vicinities. This work aims to significantly support AFAD's (Disaster and Emergency Management Authority) susceptibility maps over Konya city subsidence using satellite based interferometry using new satellite systems. Cosmo SkyMed and Sentinel-1 satellites' data evaluated using PS InSAR processing and other multitemporal technique such as Quasi-PS InSAR, SBAS methods, based on SARPROZ software package abilities. Time series of several PS points especially over Konya City Center show a general trend of the subsidence that is approximately between -40 to -60 mm/year from the both C and X band satellites, Sentinel-1 and Cosmo SkyMed.

1. INTRODUCTION

The SAR Interferometry (InSAR) application has shown great potential in monitoring of land terrain changes and in detection of land deformations such as subsidence [1]. It has a great welcome by geodesists - it is a high resolution measuring technique capable for achieving spatial information instead of typically pointwise information (as most of geodetic methods are) [2]. Within spatial information in high sensitivity for subtle movements, experts can interpret extents of subsidence associated with its temporal development, evaluate accuracy of subsidence models or compute the deformation slope angle and rate within the subsiding area - that can help in a warning against significant deformations of buildings and other infrastructure.
On the other hand, the notion of "Disaster Risk Management" is accepted all around the world especially within earth science society in recent years. Advanced and almost developing countries are trying to develop their plans and policies with particular emphasis on this aspect. Disaster risk management refers to determining, mitigating and sharing the studies about risks and principles of planning over country to region, region to city and city to local areas. Preparation of disaster scenarios, identifying priorities and the general policies and practices in order to reduce the risk of strategic planning, preparation and implementation of the application plans is part of this process.
The innovative character of the paper is thus also the focus into evaluation of applicability of InSAR to provide an early warning. To arrange a continuous monitoring system providing early warning against sudden changes or accelerations of land mass movements in both urban and non-urban areas, an appropriate multitemporal method should be chosen and tested in combination with different input dataset. In our paper we consider both low-resolution C-band SAR data of Sentinel-1 (and based also on previous experience from ERS and Envisat) and high-resolution X-band data (Cosmo-SkyMed) to understand which data are the most appropriate for automatic continuous early warning system. For continuous early warning system useful for practical application at General Directorate of Disaster Affairs centers (AFAD) of Turkey, data of guaranteed continuous acquisitions with an appropriately short temporal baseline should be selected. That is why we don't consider any other SAR system for these purposes. Usage of high frequency of acquisitions by Cosmo SkyMed and Sentinel-1 helps to identify faster terrain movements than it was ever possible before. Within this contribution we report our continuation of the work on monitoring Konya City and show the differences and potential of new sensors w.r.t. past ERS, Envisat and Alos-1 missions.

2. STUDY AREA AND OVERVIEW OF PREVIOUS & CURRENT WORKS

The study area in our work which called Konya Closed Basin is located in the Central Anatolia region of Turkey. Basin (see Fig.1), has %7 corresponding cover area rate over Turkey (~55,000 km^2), has problems with land subsidence due to groundwater extraction [3], [4]. This land subsidence signal was one of first reported in terms of geodetic applications by [5] and then investigation studies have been continued under TUBITAK (The Scientific and Technological Research Council of Turkey) project and other scientific works which related project [6], [7].

In this study it is aimed to monitor whole area from land subsidence aspect by using advanced InSAR techniques. For this achievement we separate the study area in terms of different multitemporal InSAR methods part by part over combined Sentinel coherence maps.

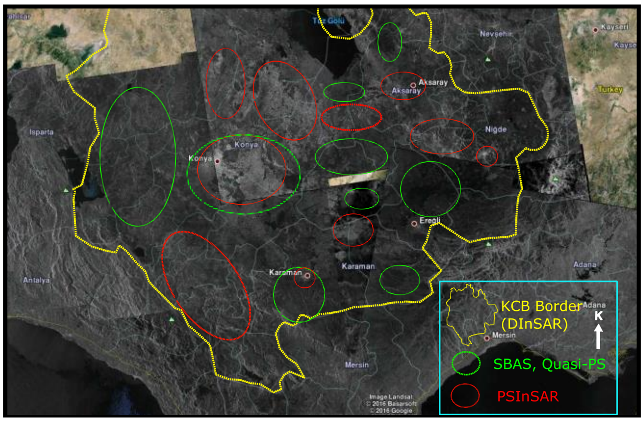

Figure 1. Classification of study area over Konya Closed Basin coherence maps and different methods of Advanced InSAR technique (Sattellite data: Sentinel-1 coherence map from 3 neighboor frame, Background image © Google Earth^{TM}, 2016)

The SAR dataset used in previous works in scope of the basin InSAR studies consists of 23 images from ERS-2, acquired from 1995 to 2000, 40 images from Envisat-ASAR, acquired from 2002 to 2012 and 10 images from ALOS PALSAR acquired from 2006 to 2011 [8], [9]. In this study, 28 images from Sentinel 1 and 20 images from Cosmo-SkyMed (CSK) acquired from 2014 to 2015 were used. Table 1 shows software and methods that were applied for these datasets and the temporal roadmap of data processing is presented in Table 2. The current processing of Sentinel-1 and Cosmo data has been performed using SarProz [10] within the framework of IT4InSAR supercomputer system [11].

Table 1. Methods and specifications scope of study

Method	*Data*	*Mode*	*Field Characters.*	*Software*
DInSAR	*Envisat ASAR, ERS-2, ALOS PALSAR*	*Desc. - Asc.*	*Urban-Rural**	*DORIS*
PSInSAR	*Sentinel-1, CosmoSkyMed, Envisat ASAR, ERS-2*	*Asc. - Desc.*	*Urban*	*StaMPS-Sarproz*
SBAS	*ERS, Envisat ASAR, Sentinel-1*	*Asc. - Desc.*	*Rural*	*StaMPS-SarProz*
Quasi-PS	*CosmoSkyMd, Sentinel-1*	*Asc.*	*Rural*	*SarProz*

**DInSAR applications for whole Basin with DORIS*

Table 2. Data processing time schedule

SATELLITES	Track - Frame	Number of Data	DATA PROCESSING TIME SCHEDULE
ERS-2	114 - 2853	23	
ENVISAT ASAR*	343,114 - 2853	40	
ALOS PALSAR	608,604-740,730	10	
SENTINEL-1	160 (orbital)	28	
CosmoSkyMed	-	20	
ACQUSITION OF DATA DEPENDING YEARS			1995 2000 2005 2010 2015

3. PS INSAR PROCESSING OF SENTINEL-1 AND COSMO-SKYMED

Both datasets cover almost the same temporal period - while Sentinel-1 data was available from 2014/10/16 to 2015/11/04, the Cosmo-SkyMed data were ordered from within 2014/10/12 to 2015/09/05 A routine application of PS InSAR for both datasets with configuration plotted in Fig. 2 and 3 was performed.

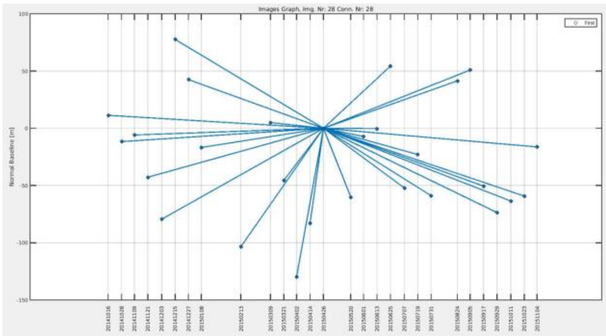

Figure 2. Sentinel data baseline combination graph for PSInSAR processing (Master image: 2015/04/26)

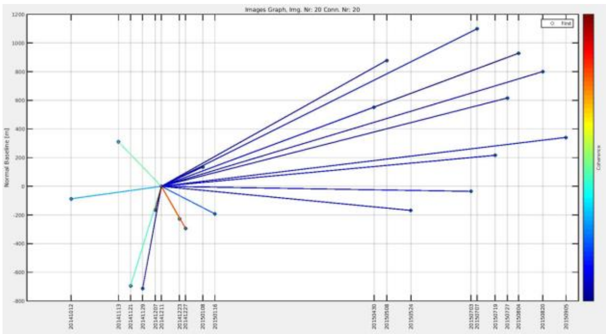

Figure 3. CosmoSkyMed data baseline combination graph for PSInSAR processing (Master image: 2014/12/11)

In the same area, ~130 000 PS points could be properly estimated from Sentinel-1 data, while ~450 000 PS points from Cosmo-SkyMed. The difference is caused by the higher spatial resolution of Cosmo data. The PS InSAR results reveal a very similar character. The mean velocity map is provided in Figures 4 while Figure 5 demonstrates a profile plot through the main subsidence bowl. Thanks to the higher spatial resolution, Cosmo SkyMed evaluated more points in the south part of the basin even though the baseline combination was not optimal for the PS processing as can be seen from Fig. 3.

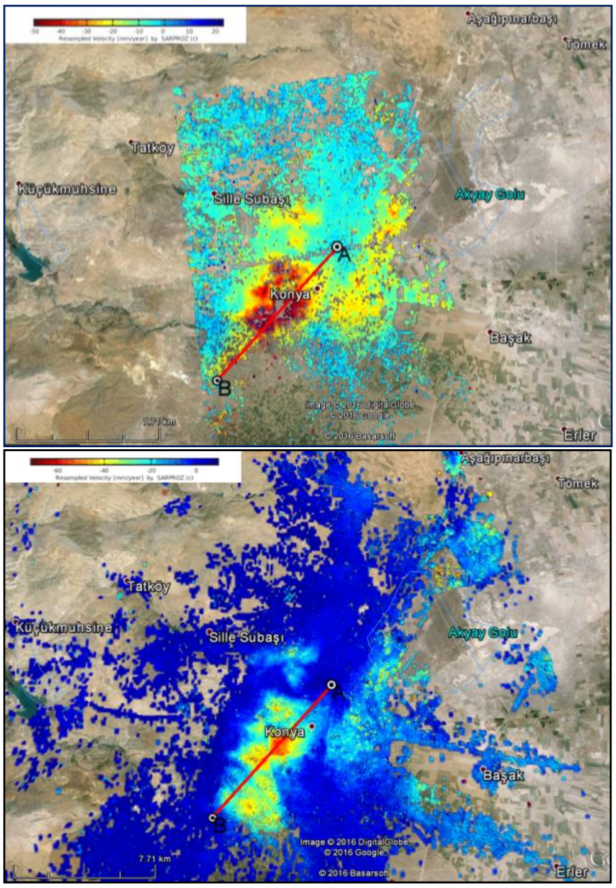

Figure 4. Mean velocity map based on PS InSAR results from Sentinel-1 (upper, colour scale from -50 to +20 mm/year) and CosmoSkyMed (lower, colour scale from -70 to +10 mm/year)

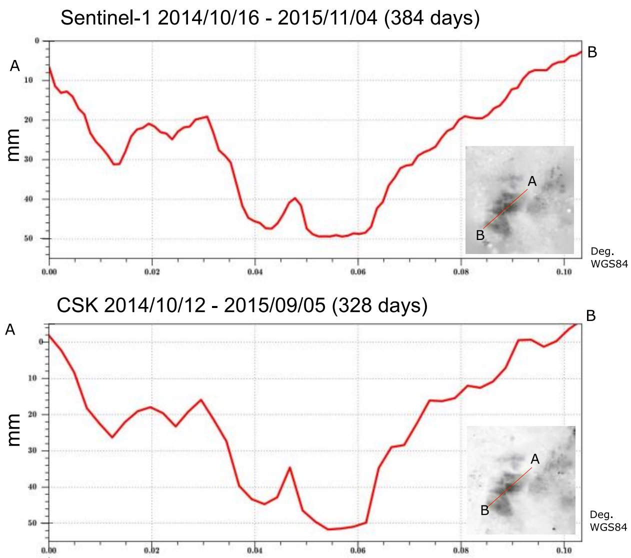

Figure 5. Profile plots of cumulative LOS displacements from Sentinel-1 (upper, 384 days) and Cosmo-SkyMed (lower, 328 days).

The subsidence of Konya city center is clearly visible from both datasets and was very similar in both cases, as is demonstrated in Figure 6. Here, contours were created from interpolated values of the mean LOS deformation velocity.

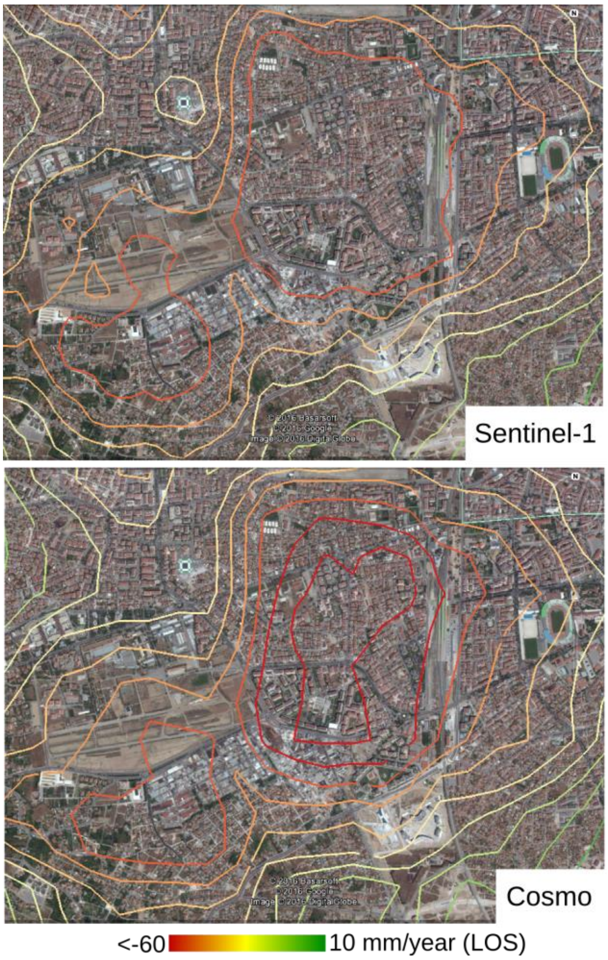

Figure 6. Contour lines from Sentinel-1 (upper) and Cosmo (lower) PS InSAR results of Konya city

The time series of PS points reveal a high rate of subsidence of buildings in Konya city center. After the recomputation from LOS to the vertical displacements, one can state that for example the building of Municipal Cadastre is subsiding in the rate of 60.5 mm/year ± 2.5 mm/year [11].

Time series of PS points corresponding to Municipal Cadastre Buildings from Sentinel-1 and Cosmo SkyMed are accounted in Figure 7. Incidence angle was 38.3° for Sentinel-1 in this location and for Cosmo Skymed it was 29.4°.

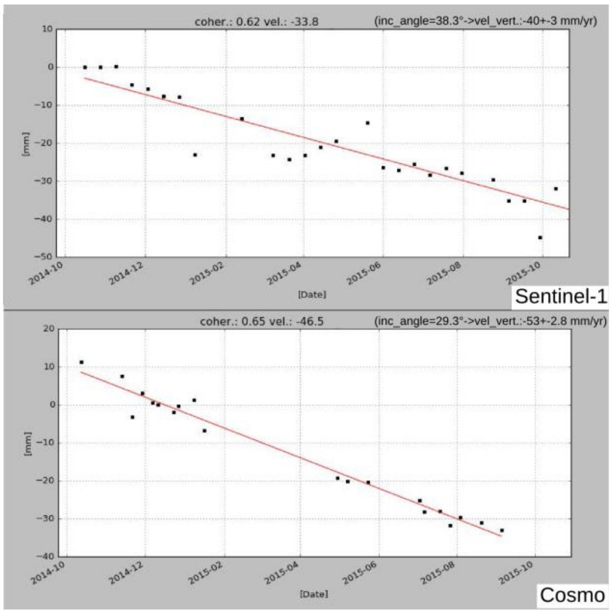

Figure 7. Time series of PS points corresponding to Municipal Cadastre Buildings from Sentiel-1 (upper) and Cosmo SkyMed (bottom).

The standard deviation from the estimated velocity trend (sigma velocity value) was for both points of Sentinel-1 and Cosmo SkyMed ~2.4 mm/year in LOS (Line-of-Sight) direction which means 3 mm/year in vertical for Sentinel-1 and 2.8 mm/year in case of Cosmo SkyMed data.

4. CONCLUSIONS

Multi Temporal InSAR processing with Sentinel-1 and CosmoSkyMed images brings significant results of detection of land subsidence as well as previous studies such GPS measurements over study area. Especially, it is effective to detect land subsidence movement at specific buildings, as shown in the example of Municipal Cadastre Buildings where a movement due to excavation works in its surrounding has been known already. This rapid and remarkable deformation (subsidence) may arise from arrangement of underground crossroads in the surroundings of observed buildings. Also one of probable reasons of subsidence is the geological history of the region forming its present appearance. The geological evolution taking place over millions of years and still ongoing particularly indicates the presence of a large debris field in Konya city center and its surroundings. Also it should be noted that the geological structure is not the only reason of subsidence. There is a higher rate of subsidence detected than was expected – the groundwater is suspected as a most probable source of these significant movements.

In this study we compare the Sentinel 1 results from October of 2014 and November of 2015 with CosmoSkyMed results from October of 2014 and September of 2015. Scope of these data and interval of time, the processing results are detected movements of subsidence in Konya and we achieved more or less the same displacement rates which is between -40 to -60 mm/year.

In order to improve these results with alternative aspects, differences of application of other InSAR processing tools or techniques should be also tested. The main objective is to evaluate if the method can be applied to provide an early warning in advance of local dangerous deformations, i.e. if the accelerated deformation changes can be detected confidently using high-resolution high-number X and C band data.

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